APPLICATIONS OF THE DQO PROCESS TO ENVIRONMENTAL DATA COLLECTION

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To make a decision you take knowledge about the world (environmental data) and select one possible action out of a set of actions. The decision is thus based on a question that you ask about the world, and the answer (from the data) will help you select an action. It is often rather difficult to translate a perceived "problem" into a clearly stated question that can unambiguously be answered with environmental data; but once this translation is accomplished, it greatly facilitates the decision. The DQO (Data Quality Objectives) process is designed to help the decision maker and staff frame their problems as answerable questions with well-defined possible courses of action and with a specified tolerance for decision error.

For the process to work, the decision maker must be able to clearly define all possible actions potentially appropriate to the question, and the actions must be distinct and not overlapping. Thus the decision maker must state how he/she is going to select among the possible actions such that only one action will be selected for each possible outcome of a well-defined decision rule.

The DQO Expert System software (DQOES) is designed to lead the decision maker and staff through a rational process that yields answerable questions with distinct action options, and produces a study design that obtains the data required for the decision, where the design neither over invests nor under invests in data accuracy relative to the actual needs. The software is interactive and encourages the user to revise text and numerical input as needed. The software also generates various DQO documentation for the user, and leads the user to well-defined, quantitative error rates consistent with the error tolerances for the decision.

We have applied the DQO process and DQOES to three Superfund case studies. For the Amnicola site in Tennessee, the DQO process was applied retrospectively to see what efficiencies result from the DQO planning process. The DQO process was used to develop the Phase 1 and Phase 2 sampling plans for the RI/FS at the Carolina Transformer site. The DQO process was used to minimize total cost of the RD/RA (sampling and cleanup) at the Piazza Road dioxin site in Missouri.

Amnicola - A retrospective RI/FS case study

The DQO process helped identify options for the decision maker. It was through the steps of the DQO process that a defensible stopping criterion and the acceptable level of uncertainty in the decision was established.

EPA Region 4 was interested in comparing the results of the DQO process to their usual design methods. The results of this comparison indicated that the usual amount of field sampling may be inadequate to define the location of the contaminants and the expected cost of alternate remedial strategies.

Possible solutions to this data quality problem were to increase the sampling budget, increase the acceptable error rates, or perform more specific and therefore less expensive laboratory analyses. Another approach to the sampling issue was to consider the consequences of gaining information about the site, and to find an optimal balance between detail gained in sampling and cleanup costs under alternate remedial approaches.

For further information please see:
Neptune, D., E.P. Brantly, M.J. Messner. Quantitative decision making in Superfund: A Data Quality Objectives case study. *Hazardous Materials Control* 4(May/June):18-27, 1990.

DQOs for Amnicola - a retrospective case study

Question:

What portion of the site poses an unacceptable risk to human health or the environment and requires remediation?

Domain:

Exposure units (EUs) are one-half acre areas of surface soil

Decision rule:

If the mean PAH concentration in an EU exceeds 122 ppm (10^{-4} risk), then that EU will require remediation

Uncertainty constraints - "Discomfort curve":

PAH risk range	concentration (ppm)	acceptable probability for false positives (%)
$<5 \times 10^{-6}$	<6.1	20
$\geq 5 \times 10^{-6}$, $<1 \times 10^{-5}$	6.1-12.2	25
$\geq 1 \times 10^{-5}$, $<5 \times 10^{-5}$	12.2-61	30

detecting something when it's not there

PAH risk range	concentration (ppm)	acceptable probability for false negatives (%)
$\geq 1 \times 10^{-4}$, $<5 \times 10^{-4}$	122-610	15
$\geq 5 \times 10^{-4}$, $<1 \times 10^{-3}$	610-1220	10
$\geq 1 \times 10^{-3}$	≥ 1220	5

failing to detect when there's something

Carolina Transformer - A RI/FS Case Study

For a second site administered by EPA Region 4, the DQO process helped integrate risk assessment and site sampling. By using the DQO process, the Region identified critical decision inputs. Where existing data were inadequate, preliminary or pilot data were collected to better determine the risk posed by the site and to identify remedial strategies.

RI/FS soil sampling was done in two phases: Phase 1 where the list of contaminants was developed and the general location was documented, and Phase 2 where costs were estimated for remedial alternatives and the location was more exactly determined.

Based on the activities at the site (transformer rehabilitation and storage), PCBs were identified as the most important and perhaps only contaminant of concern. There was no reliable information on the concentration or location of PCBs. A pilot study was recommended to assess the spatial variability of PCBs and to identify other contaminants. Since PCBs were expected to be the sole contaminant, most of the samples were analyzed by a quick turnaround method at a cost of $150 per sample as compared to $1250 per sample for the total contaminant list scan.

The pilot study indicated that PCBs were the sole contaminant at the site and that the pattern in PCB concentration fit a use-based scenario. Forty-one of 45 field samples were greater than the risk-based action level of 10 ppm. Thus most of the site presents an unacceptable health hazard. The Region accepted these data as the Phase 1 RI/FS results.

Phase 2 of the RI/FS estimated cost for alternate remedial strategies. Cost can be computed from an estimated volume of contaminated soil. The DQOES2 simulations were used to evaluate sampling designs for alternate remedial strategies. These strategies differed in the size of remedial unit (1/2 acre, 1/8 acre, 1/18 acre or 1/32 acre). An exposure unit is equal to 1/2 acre, which is based on exposure scenarios to workers at the site. Thus the decision is to remediate any RUs where the concentration of PCBs is greater than 10 ppm.

For further information please see:
> Ryti, R.T. and D. Neptune. Planning issues for Superfund site remediation. *Hazardous Materials Control* 4(Nov./Dec.):47-53, 1991.

DQOs for Carolina Transformer

Questions:

Phase 1 - What is the x, y, and z location of the contaminants on the site?

Phase 2 - Which remedial units (RUs) are unacceptably contaminated with PCBs? What is the estimated remedial cost (or volume of contaminated soil)?

Domain:

Exposure units (EUs) are one-half acre areas of surface soils. Contaminated soil will be remediated in 8" layers.

Decision rule:

Phase 1 - If any one-half acre EUs average greater than 1 ppm in PCBs, then continue to Phase 2.

Phase 2 - Determine which remedial units (RUs) within contaminated EUs need to remediated for each of the first two soil layers (0-8" and 8-16"). [Note - these data provide an estimate of the total volume of contaminated soil, which can be used to estimate remedial cost.]

Uncertainty constraints - "Discomfort curve":
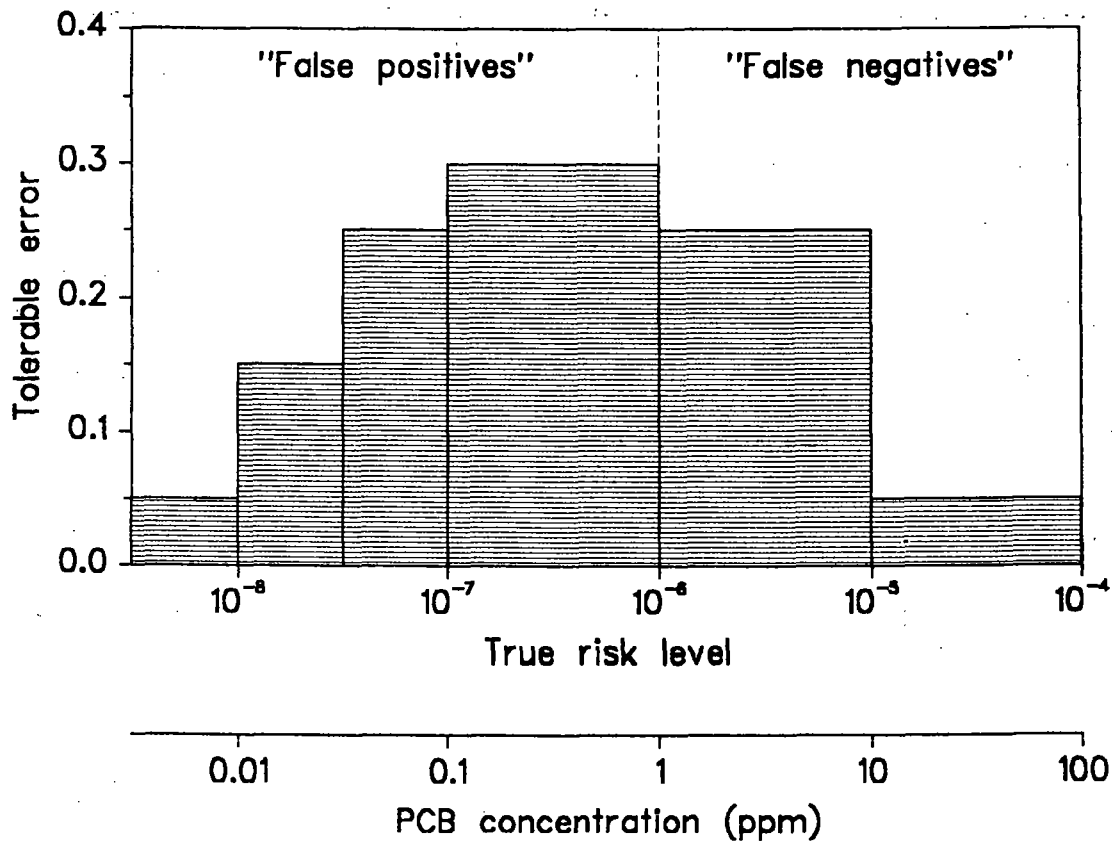
Piazza Road - A RD/RA Case Study

The DQO planning process allows managers to specify an overall goal, such as minimizing total cost of a project without compromising public health. Significant cost savings were realized at the Piazza Road dioxin site; $4,700,000 were spent on sampling and cleanup compared to $10,600,000 that would have been spent by using the historical approach.

EPA Region 7 was interested in evaluating a "surgical" cleanup approach; intensive sampling of a site better defines the portion of a site that truly represents an unacceptable health risk. More sampling (at greater cost) should lead to remediating a smaller portion of the site (at less cost). What is the optimal balance between sampling effort and the cost of remediation?

To answer this question, a statistician needs quantitative statements of the decision rule and error tolerances (e.g., false positives and false negatives). The design of choice is the lowest cost design that meets the error tolerances. To simplify the problem, the remedial decision was an all-or-none decision for each remedial unit (or cell). Cell size ranged between 100 sq. ft. and 5000 sq. ft. An exposure unit (EU) was equal to 5000 sq. ft., and the cleanup is done on an EU-by-EU basis. The "optimal" cell size would have the lowest total cost (sampling and remediation).

A pilot study was conducted to get empirical estimates of the cost of remediation for selected cell sizes. Based on these data and the sampling cost for each cell size, the total cost (sampling and remediation) was computed. A 14 ft cell size had the lowest total cost and was proposed as the cell size for the entire site RD/RA survey. This improved remediation approach was successfully applied to the site.

A "surgical" cleanup approach will only be cost-effective where the remediation cost is high compared to sampling cost. The efficacy of such an approach is also affected by the spatial distribution and concentration of the contaminant. For example, surgical cleanup of the Carolina Transformer site is not feasible for the top soil layer since it was mostly greater than the action limit for PCBs. The small scale random spatial pattern in PCBs would also make it difficult to find "clean" and "dirty" sub-units of the Carolina Transformer site.

For further information please see:

Neptune, D. and S.M. Blacker. Applying Total Quality principles to Superfund planning. I. Upfront planning in Superfund. American Society for Quality Control. Seventeenth Annual National Energy Division Conference, Tucson, Arizona, Sept. 1990.

Fairless, B. Applying Total Quality principles to Superfund planning. II. DQOs in Superfund: A dioxin case study. American Society for Quality Control. Seventeenth Annual National Energy Division Conference, Tucson, Arizona, Sept. 1990.

Ryti, R.T. Applying Total Quality principles to Superfund planning. III. Evaluation of design alternatives for a Superfund site. American Society for Quality Control. Seventeenth Annual National Energy Division Conference, Tucson, Arizona, Sept. 1990.

Ryti, R.T., D. Neptune, and B. Groskinsky. Superfund soil cleanup. *Environmental Testing & Analysis* 1:18, 1992.

DQOs for Piazza Road

Question:

What portion of the dioxin contaminated surface soil should be remediated to protect public health?

Domain:

Exposure units (EUs) are 5000 ft^2 areas of surface soils. Contaminated soil will be remediated in 4" layers.

Decision rule:

If the average dioxin concentration within an EU is greater than 1 ppb, then determine which remedial units (RUs) need to excavated to reduce the average dioxin concentration to less than 1 ppb. Size of the remedial units was determined in a pilot study (see below) that preceded the main remediation survey.
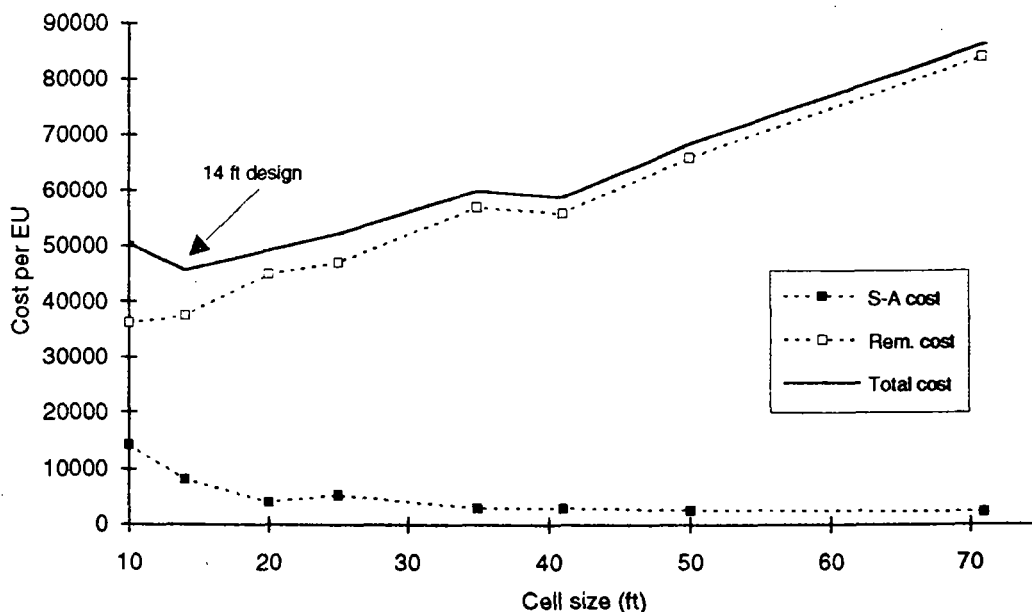
Uncertainty constraints:

Control total false negatives to less than 5% of sampled EUs

Pilot study:

Provided estimates of spatial variation of dioxin (within EU)

A test area for application of "surgical" remediation approach

Selecting the "optimal" RU size:

The projected cost per EU of cell remediation strategies. Sampling-analysis (S-A) cost was based on sampling simulations. Remediation cost was based on the pattern of contamination in the pilot area. Total cost was projected to be lowest for the 14 ft cell design.